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AUTHOR Kearsley, Greg P.
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ABSTRACT

Design considerations for instruction for the deaf are discussed in the context of a specific CAI program to teach deaf children from 10 to 15 years old in a vocational or pre-vocational stream how to use a ruler. This includes the task, learner, and means analysis involved in the development of the program. The virtues of CAI as a medium or methodology for instructional design are also considered; it is argued that the capability to provide individualized and interactive instruction, to explicitly state instructional strategies and logics, and to monitor the results of instruction makes CAI a premier choice as an instructional design tool. (Author/VT)

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Instructional Design Considerations of CAI for the Deaf

Greg P. Kearsley
Division of Educational Research Services
University of Alberta

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ABSTRACT

This paper attempts to achieve two complementary goals. The major goal is to discuss design considerations of instruction for the deaf in the context of a specific CAI program to teach deaf children how to use a ruler. This includes the task, learner, and means analyses involved in the development of the program. The second goal is to extol the virtues of CAI as a medium or methodology for instructional design. It is argued that the capability to provide individualized and interactive instruction, to explicitly state instructional strategies and logics, and to monitor the results of instruction makes CAI a premier choice as a instructional design tool.

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Greg P. Kearsley
Division of Educational Research Services
University of Alberta

Instructional design is an attempt to approach the construction and delivery of educational materials in a systematic and empirical fashion. The ultimate goal is to provide the most effective learning possible, that is, to formulate a set of principles which specify for a given student and learning task, the optimal manner in which to instruct. Clearly such principles must be reliable and reproducible if they are to amount to much.

At the present juncture, the science (or technology) of instructional design has not progressed very far in terms of developing such a set of principles. (Indeed, many educators feel that such a goal is *a priori* impossible.) It has been possible to specify heuristic rules which are likely to pay off in certain situations. What is lacking is a sophisticated medium or methodology which allows the exact recording of instructional strategies or logics used and provides detailed information on student progress and hence the effectiveness of the instruction. In fact, CAI can provide such a medium for instructional design activity.

The following discussion will briefly outline each of the three major aspects of instructional design and then consider each in terms of a CAI program to teach deaf children to use a ruler. The final section discusses aspects of implementing and testing the program which further illustrates the value of CAI for instructional design.

The three major aspects of instructional design.

Instructional design can be divided into three major aspects: task analysis, learner analysis, and means analysis. Each of these three aspects encompasses a domain of major instructional dimensions. A comprehensive instructional design will involve the dimensional interaction of these three domains. Figure 1 is a conceptual model which illustrates the interaction of the major dimensions of instructional design.

Task analysis is concerned with the "what" dimensions of instruction. The analysis of "what" dimensions is closest to what has traditionally been subsumed under the rubric "curriculum design". It involves the analysis of the characteristics of different subject matters (e.g., history versus mathematics), the particular structure of one subject (e.g., arithmetic versus topology), as well as general variables such as difficulty levels, step sizes, inherent logics and sequences, hierarchial organization, etc.

A second and very important component of task analysis is the specification of instructional objectives. In fact, task analysis is often taken to be synonymous with this dimension. While there are many differing conceptions of exactly how objectives should be specified , it is generally agreed that they should define the expected behavior of a learner after instruction has occurred. Only if the objectives are clear and explicitly stated is it possible to determine if learning actually occurred and assess how effectively. For this reason, the formulation of objectives for a particular task or subject is crucial to the overall success of instructional design. Task analysis also involves the specification of the skills or abilities which are required by a particular task or subject matter. In order to specify the nature of instruction needed, one must be able to specify what types of abilities (e.g., cognitive, affective, psychomotor) are involved and what levels. Taxonomies of learning outcomes (e.g., Bloom, Gagne) are valuable tools in the identification of levels of skills and abilities.

Learner analysis is concerned with the "who" dimensions of instruction. The analysis of "who" dimensions is necessary because instruction will be different for different types of learners for the same task or subject. A rather broad and encompassing "who" dimension is the pre-entry skills or behavior of the learner. Any instruction makes certain assumptions about the skills and abilities which the student already possesses. Failure to possess these assumed skills will almost certainly prevent the learner from benefiting from the instruction and achieving the desired learning objectives. A fairly simple example involves the understanding of instructions provided for a task. A student who lacks the necessary reading or comprehension ability to understand the instructions clearly cannot progress very far on the task. Because most tasks involve a hierarchial organization of dependent steps, failure to possess the necessary skills will eventually produce inefficient learning.

One major learner analysis dimension is age. Developmental theories (e.g., Piaget, Bruner, Kolberg, Werner) all suggest that the availability of certain abilities and skills is an age- dependent phenomenon. This means that the design of instruction must be arranged with such developmental sequences in mind. It must be determined whether or not the required skills for a task or subject are typically available at the age level of the students. Conversely, the design of instruction should take advantage of the particular skills or abilities available to the learner at a particular age. Things other than abilities change with age also; the nature of motivations, attitudes, curiosity and learning sophistication all change with age.

Another dimension of learner analysis is the population or group characteristics of the learners. This aspect of learner analysis is most evident in the design of instruction for learners with physical or mental handicaps or disabilities. It is also of obvious concern when the instruction is designed to span cultural barriers such as instruction intended for native students. Within any particular population, there are certain subgroups (e.g., poor "inner city" students versus affluent suburban students) with differences in abilities, motivations, attitudes, etc., which will require particular attention.

Individual differences are a well studied (but still poorly understood) dimension of learner analysis. Here we are concerned with differences between individuals which necessitate different instructional methods to produce equally effective learning on the same task. This includes differences in aptitudes, abilities, styles, and personality traits. Since individualized instruction is a major concern of instruction design, a sophisticated knowledge of the ways individuals differ in learning is important.

Means analysis is concerned with the "how" dimensions of instruction. The problem here is to determine what processes or procedures are necessary to teach certain types of learners and tasks. Most of the existing research in means analysis has mostly been devoted to the comparative study of different media. This research has attempted to compare the relative effectiveness of one media over another (e.g., TV versus films) as well as the best ways of utilizing a particular media. The specification of instructional strategies or modes is another major dimension of means analysis. This involves the selection of macrostrategies such as group versus individual instruction or expository (tutorial) versus exploratory (socratic) modes, and microstrategies which include the use of techniques such as shaping, fading, prompting, and so on, within any particular macrostrategy.

Student evaluation is also a major dimension of means analysis. In designing evaluation, a selection must be made between the major types possible (e.g., criterion-referenced, domain-referenced, norm-referenced) in terms of the nature and type of feedback that will best aid the learner. Evaluation will also affect the difficulty, sequence, and step size of the instruction, remedial or enrichment segments, etc. A further dimension of means analysis is motivational variables. Ways of maintaining the interest and attention of the learner must be designed if learning is to take place. Reinforcement theory provides ideas and guidance for maintaining motivation. Humor and novelty are devices also used to maintain motivation. The appropriate "mental set" may facilitate learning, an inappropriate one may inhibit it. Certain means may be used

for their motivating properties which enable learning to occur even though they do not directly contribute to learning (e.g., color).

Task, learner and means analysis are the three major aspects of instructional design. However, instructional design (and hence effective learning) is the result of interaction between these three aspects as depicted in Figure 1. Analysis of the task, learner and means dimensions is actually carried out in terms of their interaction; the separation of the dimensions is merely a conceptual one for the purposes of discussion. Thus, one studies the differences in abilities or skills across age so that one can determine what instructional strategies will be optimal for learners of those different ages. One is concerned with the individual and population differences for a certain subject matter so the appropriate motivating conditions can be arranged. Different subject matters may be most effectively presented via certain media, and so on. Instructional design is primarily concerned with understanding the complex interaction of "what", "who" and "how" dimensions to produce effective instruction. This will become clear in the following discussion of the learner, task, and means analyses involved in a program to teach deaf children how to use a ruler. [1]

Learner Analysis

The program was designed for deaf students, aged 10-15, who were in a vocational or pre-vocational stream. The major focus of the learner analysis was on the general capabilities and limitations of deaf students and the particular skills relating to the task of learning to use a ruler.

Previous work using CAI with the handicapped (e.g., Brebner & Hallworth, 1976; Sandals, 1975; Suppes, 1974) suggests:

* the use of concrete examples and minimal abstraction
* strategies which shape behavior rather than those which are didactic
* considerably more use of positive feedback than with normal students

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1. The program was written in COURSEWRITER II and implemented on the IBM 1500 system operated by the Division of Educational Research Services. The 1500 system has 20 student terminals each consisting of a keyboard and CRT display, an image projector, and an audio unit. Each terminal is also equipped with a lightpen which allows the student to respond to questions by pointing to things on the CRT screen.

* feedback messages should be constant rather than variable in nature
* screen displays should be simple and express only one idea per display
* instruction should involve as much student participation as possible

Special considerations for using CAI with the deaf are that the vocabulary and reading demands should be at a Grade 2 or 1 level and that the program should maximize the use of graphics to convey ideas and information.

In terms of the specific skills involved in learning to use a ruler, the minimal competencies which could be expected of all students were identified. These were (1) the ability to count sequentially from 1 to 16 and (2) the ability to distinquish line lengths. In addition it was assumed that all students would possess the necessary manual dexterity to hold and use a ruler, pencil, lightpen, and type at the keyboard.

The major individual difference dimension which was allowed for in the program was the degree of computational and spatial abilities. Thus one instructional strategy was designed to utilize counting ability while another involved spatial abilities. The two strategies are described below. The presence of these two strategies allowed for a matching of ability and teaching strategy in the program.

Task Analysis

The overall goal of the program is to teach students how to use a ruler as a necessary skill required in a graphic arts curriculum. The specific terminal objective for the program was that the students would be able to rule up a dimensioned form according to given specifications.

The major competencies in the task are shown in Figure 2. As the Figure shows, the task involves the blending of a set of cognitive skills with psychomotor skills. The cognitive skills involve the discrimination of line lengths, relative spatial positions of the marks on the ruler, learning the concepts of straight and parallel lines, and the rules associated with learning which fractions correspond to which specific marks. Thus, in terms of a taxonomic analysis, the cognitive components involve the skills of discrimination, concepts, and rules. The psychomotor skills required are those involved in holding the ruler and pencil, drawing straight lines, and drawing lines an exact length.

A detailed description of the task objectives in the sequence taught is given in Table 1. The first objective was designed as a connect-the-dot game. The student was presented with an array of numbered dots and instructed to

point to the dots in the correct sequential order. This served to determine that the student could count from 0 to 16 in order and also had the necessary manual dexterity to hold and use a pencil accurately. The game format created a high level of interest and motivation towards the program.

The second objective involved the presentation of varying numbers of vertical bars that the student was requested to count. This established that the student would be able to count the number of marks which denoted a particular fractional unit (e.g., 3/4, 9/16, etc.). The shaping in this objective involved presenting the bars wide apart to begin with and gradually making then closer together so that the final discrimination matched the actual discrimination required on a ruler. The third objective involved presenting the student with a number line with 0 to 12 marked on it and asking the student to identify the position of all the numbers (in a random order). The purpose of this exercise was to shape the student up to recognizing the whole units on the ruler without the complications of the fractional units.

The next objective involved learning to distinquish between a straight and non-straight line. The shaping here involved starting with a discrimination between very curved or wobbly lines and progressing to a finer discrimination between lineas which were almost straight. Having mastered the concept of a straight line, the student was then asked to draw some straight lines on paper using a ruler. The next objective presented the student with a ruler on the CRT and asked for the identification of all the unit marks on the ruler (in a random order). After mastering this, the student was then asked to draw lines of various unit lengths and hence combine the skills mastered in the previous objectives.

The following objective presents the student with a number of line segments of different lengths and asks the student to identify the longest and shortest lines. This is a necessary skill in order to be able to distinquish the different fractional marks from each other. The next objective is to actually teach all of the fractional marks in an inch. The instructional strategy used for this is described in detail in the next section. Having mastered the identification of fractional units, the next objective involved having the student draw lines of mixed (unit and fractional) lengths using the ruler.

The next objective involved teaching the student the concept of parallel lines followed by drawing various sets of parallel lines. This step is necessary in order to build the subskill for the final objective which involves drawing up a dimensioned form (consisting of many parallel columns and rows) according to specified dimensions.

The program was designed so that each objective must be mastered before the next objective could be undertaken. The criterion was generally 80% correct except for the objective dealing with the fractional marks in which 100% mastery was required. The reasoning for the setting of these criterion levels was that in a typical test of 5 questions, it is reasonable to expect the student to make one mistake due to carelessness but that 2 or more errors may indicate lack of comprehension or complete learning. The 100% standard for the fractional units was set because this subskill must be perfected to accurately use a ruler. The criteria for the psychomotor objectives involved drawing lines that were straight and within 1/16" accuracy.

With respect to the performance component of the objectives, for most of the cognitive objectives, identification of the correct answer was felt to be appropriate. Thus, being able to identify the correct position on the ruler is the actual nature of the skill required for the task and other response modes (telling, writing, etc.) were inappropriate. Obviously, the most appropriate behavior for the psychomotor objectives was drawing.

Means Analysis

In analyzing the task, an attempt was made to restrict the objectives to only those which were absolutely necessary to achieve the specified terminal objective. Furthermore, in order to minimize the learning demands of the task, a strategy was sought which would involve the simplest types of learning possible. With this in mind, it was decided to use a strategy which would not require the learning of fractions or an understanding of spatial distance. The strategy reflected in the task analysis just described involves learning how to use a ruler on the basis of the length and position of the marks. Thus, the student is taught to associate the denominator of a fractional unit with the length or size of the appropriate mark and the numerator with the position of the mark from the nearest whole inch mark. Using this strategy, the basic cognitive skills needed are the ability to discriminate line lengths and the ability to count -- both of which were considered to be pre-entry skills of the students. This instructional tactic means that it is not necessary to teach the student fractions or spatial partitioning of area which are higher order concepts and principles.

Following this strategy, the student is first introduced to the sixteenth marks and is taught to count every mark starting with the 1/16 mark in order to find the correct 16th mark. Thus, to find the 9/16 mark, the student is told to count 9 marks from the first 16th mark. To find 8th marks, the student must learn to count all the marks as

long as or longer than the 8th marks. So to find the 5/8 mark, it is necessary to count the 1/8, 1/4, 3/8, 1/2, and 5/8 marks and none of the 16th marks. The 1/4 and 1/2 marks were also taught this way (although they can simply be memorized). Some screen displays for teaching the 1/8th mark using the counting strategy are shown in Figure 3.

Because there was some doubt that this strategy would work with all students (and allow for those with high spatial ability), a complete sequence for teaching the fractional units on the basis of spatial proportions was programmed as remedial instruction. This sequence would be given if the student failed criterion on the final post-test for the objective on fractional units and also had failed criterion on the post-tests for each individual unit. It involved showing a rectangle partitioned into parts and associating the fractions with the appropriate number of parts shaded in. Next the enlarged inch was shown (same size as the rectangle) and the fractional marks shown to divide the inch into the appropriate number of parts. Screen displays illustrating this strategy for the 1/8th marks are shown in Figure 4. In contrast to the first strategy described above which started with the 1/16 mark and worked up to the 1/2 mark, this strategy started with the 1/2 mark (dividing the inch into 2 parts) and progressed to the 1/16 mark. Although both strategies started with the simplest unit, this was different depending upon whether the strategy involved the "counting" strategy or the "spatial" strategy.

The general instructional logic used in the program is depicted in Figure 5. At the beginning of each objective to be taught, instruction is presented which explains, demonstrates or illustrates the particular skill or concept involved. A post-test follows the instruction which involves the presentation of a problem/question and an indication of the desired mode of response (e.g., typing an answer via the keyboard, pointing with the lightpen, or drawing using a ruler and pencil). The student's response is then evaluated. If the response is correct, a positive feedback message will be given and another question is provided. When the student makes an initial mistake, he/she is prompted for a second try. If the next response is still wrong, an error is recorded and the correct answer is indicated to the student. When all of the available questions/problems have been presented, a test is made to see if the student has achieved the criterion for that objective. If it is met, the student goes on to the next objective. If the criterion is not achieved, remedial instruction is provided if available for that objective or the teacher is called for assistance. Thus the major role of the teacher in this program is not the delivery of instruction but rather the task of diagnosing student problems and providing remedial assistance on an individual basis.

In addition to the general instructional logic outlined, a number of other features were used in the program. In general the teaching of concepts (e.g., straight or parallel line) used the logic of presenting positive and negative instances and emphasizing the discriminating / irrelevant attributes. Directional arrows were used throughout the program as attentional cues or prompts to direct attention to aspects of the ruler or the position of marks. All student response was prompted via capital letters (e.g., TYPE or POINT).

The rate of progress through the program is set by the student as he/she controls the presentation of each successive screen display via the space bar on the keyboard. The sequence of presentation follows the organization of objectives given in Table 1 although a branching feature allowed the teacher to manually override the default sequence in order to skip an objective or review an earlier one.

Implementing and using the program.

While task, learner, and means analysis play their major role in the actual construction of a program, instructional design activity does not stop once the program is completed. In fact, the revision of the program on the basis of student feedback is a crucial part of optimizing the instruction. In the case of CAI, this means studying the detailed performance recordings of all the students for each and every instructional sequence in the program.

A number of changes related to inadequacies of the task analysis were made in the program. The instruction on fractional units was modified so that the post-test for each unit would review all of the previous units not just the most immediate one taught. Thus, the test for the 1/8 marks also included the 1/16 marks and the test for the 1/4 marks included the 1/8 and 1/16 marks. Originally, only the final post-test for the entire unit had tested all of the marks at the same time. This modification reflected a gap in the original task analysis, namely, the skill of integrating or synthesizing each new fractional unit with the preceding units. In fact, the results suggested that this was one of the crucial subskills in the entire task as indicated by the failure of many children to get beyond this step.

Another change to the fractional units involved the inclusion of a "count with me" prompt when the student failed to pick the correct mark in the counting strategy. This involved displaying the message "Count the marks with me" and then pointing to each of the successive marks while also showing the numbers. This demonstrated the correct use of the counting strategy and allowed them to figure out what they had done wrong. Originally, an arrow would have pointed

to the correct mark and they would have been told that their selection was "Wrong". The original correction procedure showed them the right answer but did not help them discover what they had done incorrectly.

The last objective was also modified. It was clear that the step size from the objective of drawing parallel lines and that of drawing up a dimensioned form was too large. Instead of asking the students to immediately draw up a page-size dimensioned form, they were asked to draw a series of dimensioned forms beginning with a simple box and working up to more complicated forms. Thus, more shaping was necessary in order to achieve the final objective. In addition, it was necessary to point out to the students that the final dimensioned form would occupy the entire page. This was a minor (but important) aspect which had been overlooked in the original task analysis.

In addition to the changes to the instructional content, a major change was made to the instructional logic. According to the original logic, if a student failed a post-test criterion for an objective, a message was displayed on the screen telling the student to call for the teacher's help. The teacher would watch as the student went through the post-test again and diagnose the problem. It was felt that a single time through each unit provided insufficient practice and also necessitated an excessive demand for teacher assistance. In view of this, the logic was changed so that when a student failed a post-test, they would be branched back to the beginning of the post-test again. If the student failed the post-test on the third attempt, then the message was displayed and teacher assistance called for. The general effect of this change was to increase the amount of drill and practice the student received in the program.

With respect to instructional strategies, it was found that most students had considerable difficulty understanding the counting strategy when it came to the 1/8 marks and they had to learn the rule to count all the marks as long as or longer than the 1/8 marks (but not the shorter marks). Using this rule apparently demanded considerable reasoning ability and hence made the counting strategy much more difficult than we had expected (since it only involved the subskills of counting and discriminating line size). The introduction of this rule was amplified and the student was asked to identify all the lines which were as long as or longer than the 1/8 marks. Although these modifications made the rule easier to learn it became apparent that this step called for reasoning skills which were beyond the capabilities of most of the students...hence a failure in the initial task and learner analysis.

Conclusions

This paper has discussed instructional design considerations of CAI for the deaf as exemplified by a specific program about the use of rulers. Hopefully, the discussion has brought out the nature of task, learner, and means analysis in the context of CAI. The important conclusion to be drawn from all this is that CAI itself possesses no magic which will turn poor teaching into good teaching. It does, however, provide a medium which permits individualized and interactive instruction, exact documentation of instructional strategies and logics used, and detailed monitoring or student performance and this facilitates considerably the design of better instruction.

ACKNOWLEDGEMENTS

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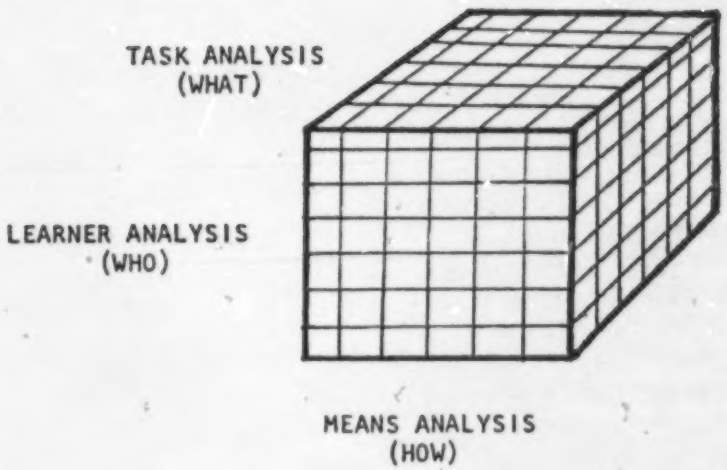
TABLE 4

Instructional Objectives.

CONDITIONS	PERFORMANCE	CRITERIA
1. Given a series of dots numbered from 0 to 16 on the screen	Using light pen, points to the dots in successive order	Each dot constitutes one trial. No more than 3 errors for all 16 trials
2. Given a series of vertical bars in sets of 1 to 16 on the screen	Counts the number of bars and types in the answer	5/5 Correct
3. Given the numbers from 0 to 16 in random order and a linear scale with 12 equally spaced numbered intervals on the screen	Using the lightpen, points to the correct position on the numbered scale	10/13 Correct
4. Shown a series of straight and curved lines in pairs with the discrimination becoming more difficult for each pair	Using the lightpen, points to the straight line in each pair	4/5 Correct
5. Given illustrations of the correct way to hold and position the ruler, pencil, and paper, and using a pencil and ruler	Draws straight lines between indicated crosses (x) on paper	7/8 Correct
6. Given display of standard ruler on the screen	Using lightpen, points to the whole inch marks	4/5 Correct
7. Given instruction on the screen about how to draw measured line lengths and pencil and ruler	Draws lines of whole inch lengths always starting at the 0 mark	4/5 Correct
8. Given a series of line segments of different lengths on the screen	Using lightpen, points to the shortest and longest line segments	2/2 Correct
9. Given instruction on finding 1/2, 1/4, 1/8 and 1/16 marks on ruler and enlarged 1 inch portion of ruler on screen	Using lightpen, points to all fractional marks	100% mastery. Must be with 1/16"
10. Given instruction about combining whole and fractional marks and display of full ruler	Using lightpen, points to correct mark	4/5 Correct
11. Given ruler and pencil and directions on screen	Draws lines of mixed fractional lengths	13/16 trials correct with 1/16" accuracy
12. Given a series of parallel and non-parallel lines in pairs and instructions on the screen	Indicates (by typing yes or no) whether pairs of lines are parallel	4/5 Correct
13. Given instruction on how to draw parallel lines via illustrations and pencil, ruler and paper	Draws parallel lines a specified distance apart	3/4 Correct with 1/16" accuracy
14. Given instructions on the screen, a dimensioned sketch, and pencil, paper, and ruler	Draws a dimensioned form according to specifications	Each line is 1 trial, Form consists of 8 lines 7/8 trials correct with 1/16" accuracy

FIGURE 1

MAJOR DIMENSIONS OF INSTRUCTIONAL DESIGN



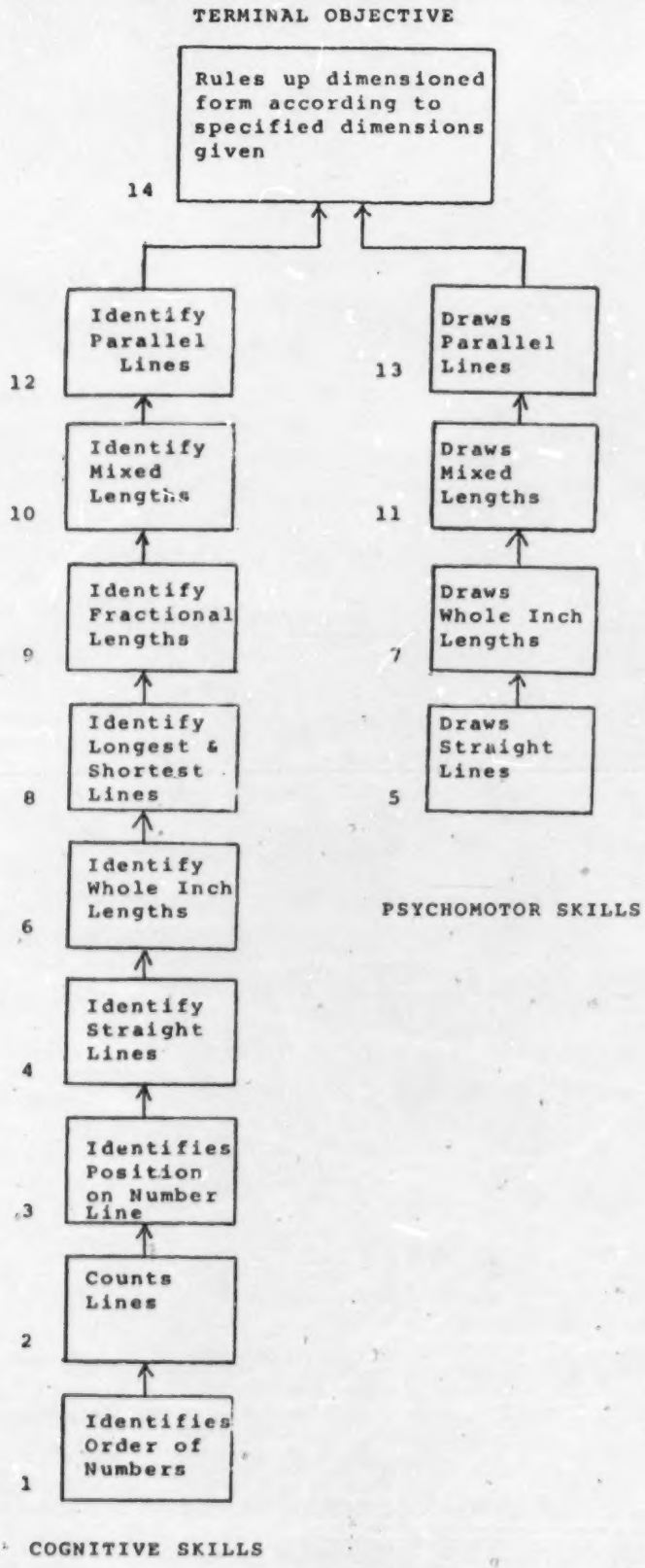


Figure 2. Competencies required by task.

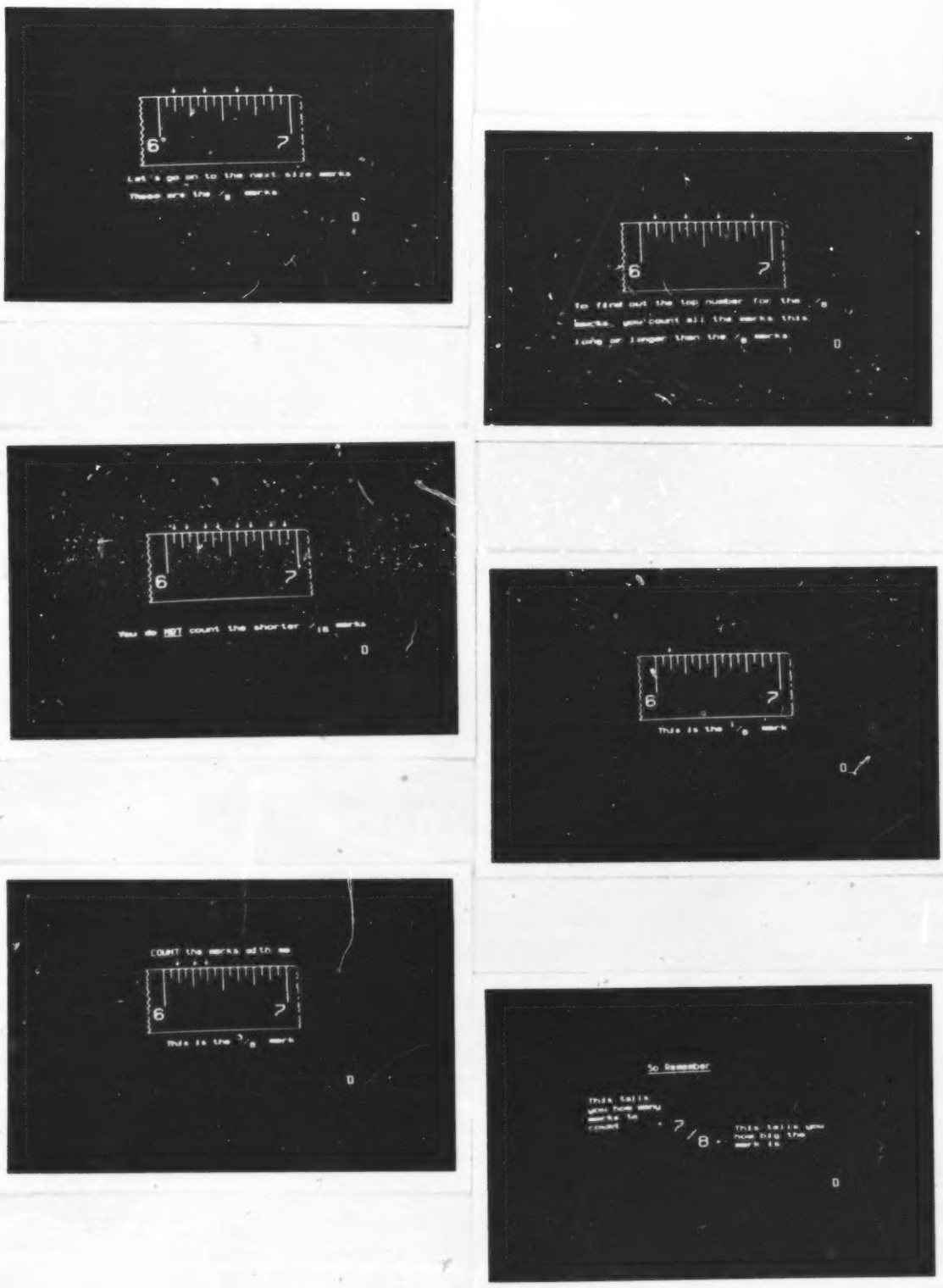


Figure 3. Screen displays for teaching the 1/8 mark using the counting strategy.

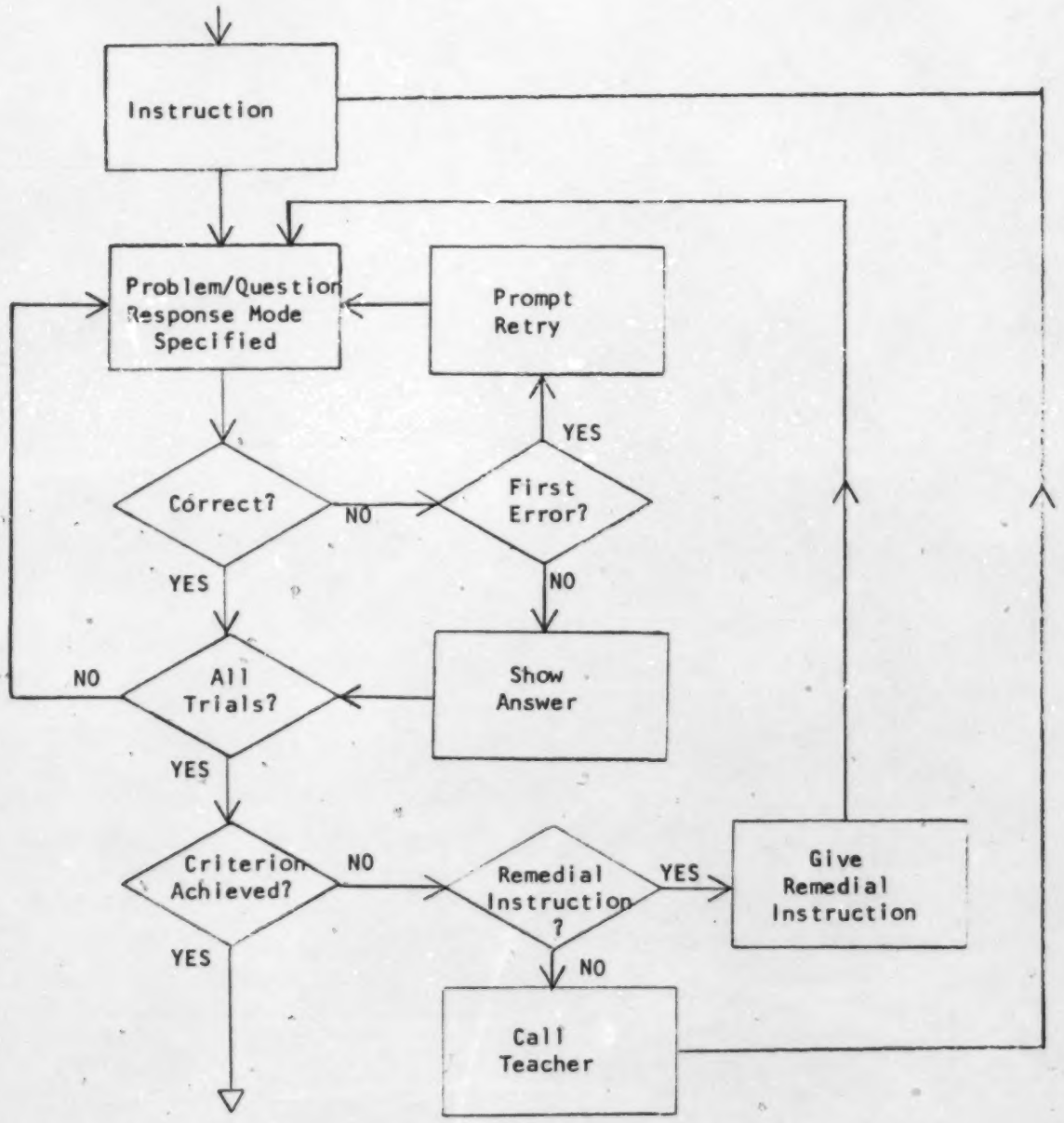
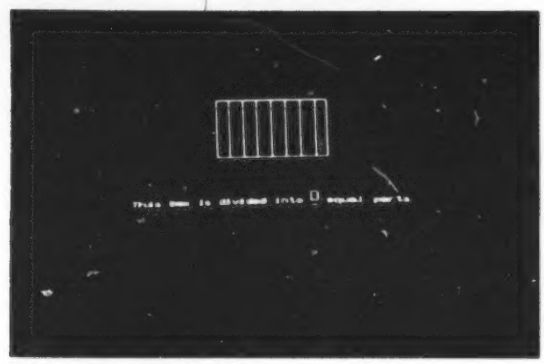
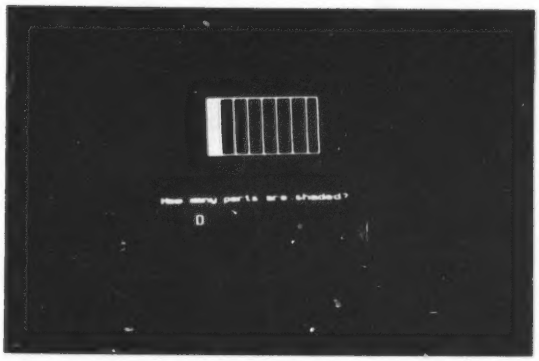
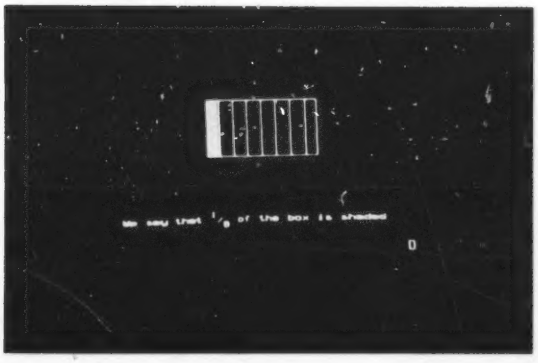
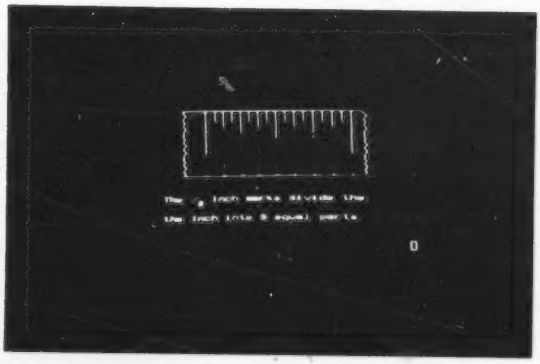


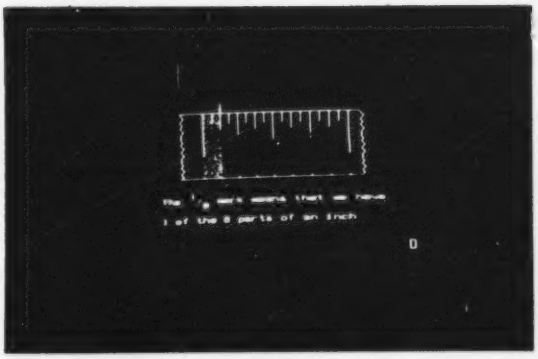
FIGURE 5. General Instructional Strategy Used in Program.











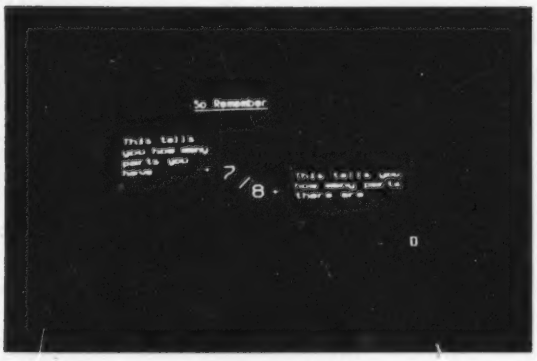


Figure 4. Screen displays for teaching the 1/8 mark using the spatial strategy.